

RELATIONSHIPS BETWEEN HEATH AND *LEPTOSPERMUM LAEVIGATUM* SCRUB AT SANDRINGHAM, VICTORIA

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Regeneration of vegetation following burning was studied at 5 sites on 2 small urban reserves at Sandringham, Victoria. These reserves were covered before colonial settlement with *Casuarina pusilla*-*Leptospermum myrsinoides* heath but parts had since been invaded and dominated by *L. laevigatum*, producing a species-poor scrub. Burning of the scrub dramatically increased the number of native species present, largely by causing germination of soil-stored seed. With appropriate weeding, especially in the first six months post-fire, a significant subset of the original heath vegetation can be returned to such sites by burning, even in the absence of an adjacent heath seed source.

A soil seed bank experiment demonstrated germination enhancement by heat for Epacridaceae, *Isolepis* and *Olearia ramulosa*. The last is an important post-fire pioneer which appears to suppress regeneration of some other native species.

Contrary to some previous views, fruits and seeds are not retained on *Leptospermum laevigatum* for a number of years. In this area, seed shed may be almost complete by late spring–early summer of the year following spring flowering, and most fruits also fall within a year. As soil storage of seeds is minimal, spring fires may cause lower densities of *L. laevigatum* seedling regeneration than summer–autumn ones, when burning can release much ripe seed.

L. laevigatum can invade various heaths, woodlands and scrub in the absence of fire or obvious disturbance. Some management recommendations are made for areas where it is intended to burn sites now dominated by *L. laevigatum* scrub in order to re-establish heath species.

IN VICTORIA, well-drained coastal sands commonly carry *Leptospermum laevigatum* scrub and, landward of this, *Casuarina pusilla*-*L. myrsinoides* heath. In some areas these communities may be seral and climax respectively. In the last 50 years, however, *L. laevigatum* has invaded such heaths in a number of places, often forming a closed scrub and eliminating them (Burrell 1981). Little is known of the role of fire regime either in causing such changes or in reversing them. Here, we examine this subject especially by investigating two heath sites which have been invaded, converted to scrub and then burnt in fires lit by vandals.

THE STUDY AREAS

The areas are 0.5 km apart in the suburb of Sandringham, 15 km south-east of central Melbourne where climate is the humid mild-winter (Cfb) Köppen type with cool summers and an evenly distributed rainfall (Dick 1975) averaging 725 mm per year. At all sites sampled, the soils are deep siliceous sands without impeding layers to at least 2.5 m.

Bay Road Heathland Sanctuary and George Street Reserve together provided three burnt and two unburnt sites; all carried heath before colonial settlement (Table 1). All aerial plant parts were killed in the burnt areas. At George Street all fire-killed *L. laevigatum* stems were cut down, some removed and some piled up and burnt on site.

Post-fire hand weeding was applied to *Acacia saligna*, *Arctotheca calendula*, *Phytolacca octandra* and alien grasses (especially *Ehrharta erecta*) at Bay Road, to *Chrysanthemoides monilifera*, *Hypochoeris* spp. and *Muehlenbeckia adpressa* at George Street and to *Acacia sophorae*, *Chamaecytisus proliferus* and *Leptospermum laevigatum* seedlings at both sites.

Heath was sampled at Bay Road as the only available guide to the vegetation at the four main sites (Table 1) before colonial settlement.

METHODS

Standing vegetation

Sampling was associated with two different projects. Initially, one of us (DF) set up and sampled

Site	Pre-fire vegetation	Date of fire	Post-fire treatment	Notes*
RLU	<i>Leptospermum laevigatum</i> scrub	Unburnt	None	Site has been dominated by <i>L. laevigatum</i> for about 50 yrs
RLB	As above	January 1985	Removal of some alien plant species (see text) and of some seedling <i>L. laevigatum</i> and <i>Acacia sophorae</i>	As above
RHB	<i>Casuarina pusilla</i> - <i>L. myrsinoides</i> heath	January 1985	Removal of some alien plant species (see text)	
GLU	<i>L. laevigatum</i> scrub	Unburnt	None	Site has been dominated by <i>L. laevigatum</i> for about 70 yrs
GLB	As above	October 1984	Removal of some alien plant species and of some seedling <i>L. laevigatum</i> and <i>A. sophorae</i>	As above

*Based on aerial photographs, historical records and residents' recollections.

Table 1. Characteristics of the five sites studied; all originally carried heath. R = Bay Road Heathland Sanctuary; G = George Street Reserve; L = *Leptospermum laevigatum* scrub; H = *Casuarina pusilla*-*L. myrsinoides* heath; U = unburnt; B = burnt.

single 10 × 10 m permanent quadrats at sites RLB and RHB at 3, 12 and 20 months post-fire and at GLB at 15 and 23 months post-fire (see Table 1 for details of sites). The Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974) was used except that scale value 2 = 5–20% cover, 3 = 20–50% and 4 = 50–75%.

Subsequently, 29 to 32 months post-fire (Table 2), CDM and RFP sampled cover at all five sites using 30 m line-intercepts (Hanes 1971). The small size of sites restricted replicates to two per site and meant that each 30 m replicate had to be broken into six 5 m lines. Plants with an intercept length of less than 10 mm were arbitrarily assigned a length of 2 mm; other intercept methods follow Hanes (1971). The intercept lengths were then converted to the above cover scale values to allow comparison with the initial samplings (Table 2).

The final samplings, in June 1987, will have underestimated some annual and seasonal perennials. Nomenclature for vegetation follows Specht (1970), for plant species follows Forbes & Ross (1988) and for post-fire regeneration modes follows Naveh (1975).

Soil seed bank

Four replicate soil cores (75 mm diameter) to 100 mm deep from each site were collected and sieved (4 mm sieve). Half of each replicate was

exposed to aerated steam in a soil-steam sterilizer (see Wareup 1980) so that soil temperature reached about 60°C. Whereas duration at this temperature was 30 minutes on the surface of each sample, it was much less than this in the centre of each. Both heated and untreated soils were spread to 10 mm depth over 15 mm deep Perlite in drained 280 × 340 mm plastic trays.

All trays were watered as required from 18 May to 5 October 1987 in a partially heated glasshouse. Seedlings were identified and discarded or transplanted and grown on until identifiable. After three months, all soils were stirred to encourage further germination. Control trays failed to detect any glasshouse seed contamination.

Leptospermum laevigatum reproduction

Regeneration was quantified by density measurements at all sites in August 1987. General observations were made of seed and fruit fall over an eight year period. Viable seed was estimated from squash tests.

RESULTS

Standing vegetation

At site RLB three months after fire, the most common species, *Bossiaea cinerea*, occurred with nine alien and five native species (Table 2). Dense *Olearia ramulosa* was predominant by 12



Fig. 1. Site RLB in August 1987, 30 months post-fire, showing fire-killed stems of *Leptospermum laevigatum* and dense regeneration of *Olearia ramulosa* 1.6 m high (from seed).

months and remained so throughout the rest of the study, becoming 1.5 m high. *Acacia sophorae* and *Leptospermum laevigatum* became common from three to 12 months along with *B. cinerea*. In this period, the aliens *Chamaecytisus proliferus* and *Phytolacca octandra* were weeded back from cover value 4 to cover value 1. Species richness reached a maximum of 15 alien species

and 30 natives. Over the succeeding 17 months, *O. ramulosa* became taller and with higher cover values while native species richness declined rapidly to 11 species (Table 2).

Unlike site RLB, vigorous rootstock regeneration of shrubs occurred (at the nearby burnt heath site, RHB). *O. ramulosa* cover values never exceeded 3 and native species richness declined only slightly (from 34 to 30) in the period from 12 months to 29 months after fire (Table 2).

At site GLB 15 months post-fire, the most common species were *Isolepis nodosa* and *Acacia sophorae*. The aliens *Chrysanthemoides monilifera*, *Chamaecytisus proliferus* and *Hypochoeris* spp. had already been weeded back from 2 to +, + and 1 respectively (+ = few, with small cover). By 23 months, *Isolepis nodosa* had disappeared and *A. sophorae* had been weeded back to a cover of +. Native species richness reached a maximum of 29 species. In the period from 23 to 32 months, *Bossiaea cinerea* predominated. *Lepidosperma concavum* was also common as were two prostrate perennials more typical of early seral stages in coastal dune successions, the native *Muehlenbeckia adpressa* and the alien *Carpobrotus edulis*.



Fig. 2. Site GLB in August 1987, 35 months post-fire, showing heath 1.2 m high. Prominent species in foreground include *Olearia ramulosa*, *Acacia sophorae* and *Bossiaea cinerea*. Unburnt *Leptospermum laevigatum* scrub 7 m high in background previously dominated whole area.

	+	1	3	2	1	1	450	210
IRIDACEAE	FR							
* <i>Romulea rosea</i>	OR							
* <i>Tritonia</i> sp.		1						
JUNCACEAE								
<i>Juncus pallidus</i>	FR	+				+		
<i>Juncus</i> sp.	FR							
? <i>Luzula</i> sp.	?							10
LILIACEAE								
* <i>Allium triquetrum</i>	?							1
<i>Burchardia umbellata</i>	OR	+	+	2	3			
<i>Caesia parviflora</i>	OR			+				
<i>Dianella revoluta</i>	OR	1	2	2	#	1	1	1
<i>Dichopogon strictus</i>	OR				1		2	2
<i>Laxmannia sessiliflora</i>	OS	+					2	1
<i>Lomandra filiformis</i>	OR		3	5	1	2		
<i>Thysanotus patersonii</i>	OR	+	+	#	1			
<i>Xanthorrhoea minor</i>	OR		+	2	2	1		
ORCHIDACEAE								
<i>Acianthus exsertus</i>	OR	1						
<i>Microtis unifolia</i>	OR			1				
RESTIONACEAE								
<i>Hypolaena fastigiata</i>	OR		3	2	2	2	1	30
DICOTYLEDOONS								
AIZOACEAE								
<i>Carpobrotus rossii</i>	OS			+				
* <i>Carpobrotus edulis</i>	OS							(80)
CARYOPHYLLACEAE								
* <i>Stellaria media</i>	OS	+						
* <i>Cerastium</i> sp.								
CASUARINACEAE								
<i>Casuarina pusilla</i>	FR	1	1	1	+	+	1	
CHENOPODIACEAE								
* <i>Chenopodium</i> sp.	OS							
COMPOSITAE								
*+ <i>Arctotheca calendula</i>	OS	+						
<i>Cassinia aculeata</i>	OS							
*+ <i>Chrysanthemoides monilifera</i>	OS	+		+				
* <i>Coryza botariensis</i>	OS	1						
<i>Cotula australis</i>	OS	+	1					
*+ <i>Hypochoeris</i> sp.	OS	+	+	+	+			

Table 2. Mode of regeneration, cover values (at four intervals since fire) and soil seed bank at five sites; * = alien species; + before generic name = species reduced by weeding; # = recorded outside quadrats; ? = unknown; OS = obligate seedling regenerator; FR = facultative resprouter; OR = obligate resprouter; seedbank values in parentheses indicate seedlings that could only be determined to genus.

[illegible]

The percentage of alien species at sites RLB, RHB and GLB was 21, 6 and 11 respectively.

Olearia ramulosa plants first flowered in their second spring post-fire; *Acianthus exsertus* flowered profusely in the first flowering season following the fire.

The unburnt scrub sites, RLU and GLU, had *Leptospermum laevigatum* cover values of 5 and very few other species. The only native species, recorded occasionally, were *Pteridium esculentum*, *Acacia sophorae* and *Bossiaea cinerea*.

Soil seed bank

Because of low seedling numbers and lack of clear differences between heated and unheated treatments for many species, most data were bulked across treatments (Table 2). A heat effect was clear, however, for three species (Table 3).

Of the total number of species recorded in both the standing vegetation and seed bank, 7% occurred only in the seed bank, 56% only in the vegetation and 37% in both. The larger number of species recorded in unburnt than burnt sites (Table 2) is presumably related to seed bank depletion due to fire encouraging germination of some species and possibly also destroying some seed.

Leptospermum laevigatum reproduction

Leptospermum laevigatum post-fire densities (plants/m²) for the five sites were RLB 13.7, RLU 0.2, RHB 1.5, GLB 0.8 and GLU 0.3. Despite the small amount of *L. laevigatum* weeding in the first year post-fire at RLB and GLB, the most striking point is the much higher density at RLB than at any other site including the other burnt *L. laevigatum* stand (GLB).

Mean number of viable seeds per 1986 fruit was 20.

DISCUSSION

Standing vegetation

About 79% of the native RHB species have the ability to resprout after fire, a similar percentage to that found by Purdie (1977) and McMahon (1984). By contrast, only 53% and 51% of native species were resprouters at RLB and GLB respectively (Table 4). A significant number of native species at RHB, especially obligate resprouters, do not occur at RLB and GLB post-fire (Tables 2 & 4). Of all the native species recorded at RHB, 69% were recorded at least once at RLB or GLB.

Sites	Soil seed bank (mean number of viable seeds/m ² to 100 mm depth)									
	RLB		RHB		GLB		RLU		GLU	
	Heated	Unheated	Heated	Unheated	Heated	Unheated	Heated	Unheated	Heated	Unheated
Taxa										
<i>Isolepis nodosa</i>	870	210	30	—	9980	2000	180	240	1210	710
<i>Olearia ramulosa</i>	180	—	450	—	—	—	550	110	80	130
<i>Epacris impressa</i>	—	—	130	—	—	—	—	—	50	—
<i>Leucopogon virgatus</i>	—	—	—	—	—	—	—	—	—	—

Table 3. Seed bank values for heated and unheated soils from five sites for three plant taxa.

Site	Obligate seedling regenerators		Faecultative resprouters		Obligate resprouters		Total native species (all samplings)	Number of native species June 1987)
	Number	Percent	Number	Percent	Number	Percent		
RHB	9	21	20	48	13	31	42	26
RLB	18	47	16	42	4	11	38	11
GLB	18	49	15	40	4	11	37	24

Table 4. Modes of post-fire regeneration for native plant species from three sites (excluding four species of unknown regeneration mode).

It is clear that a significant subset of the original heath vegetation can return to such sites after burning, even after 70 or so years of *Leptospermum laevigatum* dominance and even in the absence of an adjacent heath seed source, as at George Street. There, no regeneration occurred of the three most dominant shrubs of heath in the area, *Casuarina pusilla*, *Leptospermum myrsinoides* and *Banksia marginata*, while the adjacent heath seed source at Bay Road meant that seedlings of all three occurred in site RLB post-fire.

As usual, some short-lived obligate seedling regenerators normally only found post-fire were recorded ("post-fire pioneers"). These were *Xanthosia pusilla* (see also Russell & Parsons 1978, Wark et al. 1987) and *Olearia ramulosa*. Even though *O. ramulosa* seems not to be normally recorded in heath sites (Jessop & Toelken 1986, A. McMahon pers. comm.), it strongly dominated site RLB, possibly arising from seeds from live old plants 10 m away. A close analogue to the behaviour of *O. ramulosa* is that of the composite *Ixodia achilleoides* which dominates shrubby forest understories in the Mount Lofty Ranges for 3–4 years after fire. It too grows much faster than *Leptospermum myrsinoides* and is strongly dominant before senescing and disappearing (Wood 1937).

An important management problem at RLB and GLB is that the virtual absence of post-fire competition by rootstock regenerators allows dense stands of some seedling regenerators like *Olearia ramulosa* and *Acacia sophorae* to develop and these can suppress regeneration of other species. This is made more serious at sites like Bay Road where there has been significant soil disturbance, foot traffic and rubbish dumping, as the same effect allows large populations of weeds like *Chamaecytisus proliferus* and *Phytolacca octandra* to develop.

Of the species forming dense post-fire patches and stands, there is a group of native ones, namely *Acacia sophorae*, *Carpobrotus rossii*, *Muehlenbeckia adpressa* and probably *Olearia ramulosa* which are normally not found in heath but in earlier seral stages of beach dune succession on soils more fertile than heath ones. Perhaps disturbance and deposition of litter by visitors in these small urban reserves is increasing soil fertility and allowing such invasion by species from earlier seral stages; this would parallel the way that increased phosphorus level from such causes has led to marked deterioration of very similar heath communities elsewhere (Hedde & Specht 1975). Comparing

the RLB data with the RHB data highlights the way in which the intrusion by the native species listed above and by alien weeds is greatly reduced by the vigorous rootstock regeneration recorded at RHB.

Regarding the dense stands of the South African *Carpobrotus edulis* which developed post-fire at GLB, the same phenomenon has been noted in Western Australia and in California, where it is assumed that soil storage of hard-coated seeds is involved (Zedler & Scheid 1988).

Soil seed bank

In general, total number of germinates increased with increasing site disturbance, as found by Major & Pyott (1966). It is likely that not all seed present in the samples germinated, given the limited range of environmental conditions employed. Absence of Myrtaceae may be due to lack of soil storage of seed in this family (Ashton 1979, Clemens 1986).

Germination enhancement by heat for Epacridaceae and *Isolepis* was also recorded by Warcup (1980), who referred to *Isolepis* as *Scirpus*. Such enhancement is more unexpected for *Olearia ramulosa*, although similar behaviour occurs in the composite *Chrysanthemoides monilifera* (Weiss 1986). It is not known if heat enhancement has a role in the post-fire mass germination of native composites like *Helichrysum obtusifolium* and *Olearia teretifolia* (A. McMahon pers. comm.).

Leptospermum laevigatum reproduction

In 1987, flowering was first noted as sparse on 9 August and was common by September, in accordance with the accepted flowering time of late August to November (Burrell 1969). Seeds are thought to become ripe during the summer after flowering (Hazard & Parsons 1977; this study). Ripe fruits start opening within hours of a branch being cut or exposed to fire (Burrell 1981).

Our observations strongly suggest that shedding of seeds initiated the previous spring is virtually complete by late spring–early summer and probably reaches its peak as early as the January–February after flowering. Most fruits also fall within a year. Similarly, Wrigley & Fagg (1979) and Clemens (1986) noted that seeds and fruits are not retained on the plant for more than a year. Taken together, the available data suggest abundant seed shed in the absence of fire and little or no retention of fruits on-canopy for

more than a year. We do not agree that, generally, "most of the capsules remain attached to the plant for a number of years" (Burrell 1969).

Field germination is from May to early October (Burrell 1969). Soil storage of seed is minimal, probably due largely to seed harvesting by ants (Burrell 1969, van Gameren 1977, Clemens 1986). The combined effect of these characteristics and of seed fall within a year of flowering may be to cause lower densities of seedling regeneration after spring fires, like the early October one at GLB, than after summer-autumn fires, like the late January one at RLB. We assume that at RLB virtually the entire 1984 seed crop was ripe and released from the canopy by the fire, so that RLB had both larger seedfall and less seed predation before autumn germination than GLB, where fire presumably destroyed most or all of the not fully mature 1984 seed crop. In managing vegetation to minimize rate of *Leptospermum laevigatum* invasion, spring burns before the maturation of the current fruit crop may be preferred to autumn ones.

The fruiting behaviour inferred here for *L. laevigatum* is strikingly different from that of *L. juniperinum*, in which fruits are retained on the plant for at least six to eight years, whilst increasing in size and fleshiness (Ashton 1986).

Leptospermum laevigatum is now naturalized in South Africa and, because it can be invasive and exclude native species by forming dense stands, is becoming widely recognized as an environmental weed in Australia (Kloot 1985, Adair 1987). The work published so far on *L. laevigatum* invasions gives the strong impression that fire is necessary to allow invasion into native vegetation (e.g. Burrell 1981). It is now clear that such invasion can occur in the long-term absence of fire or other obvious disturbance; for example, the invasion into heaths near Portland and Anglesea, into *Leucopogon parviflorus* scrub at Cape Otway and into various woodlands on the Mornington Peninsula, all in areas which have remained unburnt for several decades (G.W. Carr and A. McMahon pers. comm.). One of the factors favouring such *L. laevigatum* invasions may be declining fire frequency near human settlements, as suggested by McMahon, Carr & Bedgood (1987).

Regarding management of small coastal reserves like those studied here, where sites now dominated by *Leptospermum laevigatum* may be burnt to try to re-establish heath species, we stress the following points:

(a) The first six months post-fire are critical to the long term success of the regenerating in-

digenous seedlings. Removal of weed species in this period significantly reduces the loss of indigenous seedlings to rampant weed growth. As the cover of indigenous seedlings increases, weed invasion decreases and the need for intensive hand weeding is reduced.

(b) While burning in spring reduces invasion by *L. laevigatum* and alien grasses (like *Ehrharta* spp.), *Acacia sophorae*, *Chrysanthemoides monilifera* and *Hypochoeris* spp. can become serious threats. If intensive follow-up weeding by paid staff and/or volunteers is unavailable after controlled burning, it is best not to burn until provision for weeding is made. The benefits of burning to stimulate regeneration are rapidly lost to invading weed species.

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